LLNL Environmental Report 2006

Chapter 6 Terrestrial Monitoring

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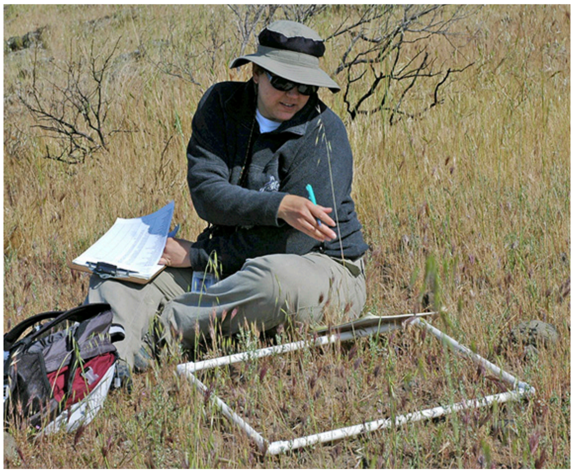

Lawrence Livermore National Laboratory monitors several aspects of the terrestrial environment. LLNL measures the radioactivity present in soil, sediment, vegetation, and wine, and the absorbed gamma radiation dose at ground-level receptors from terrestrial and atmospheric sources. In addition, LLNL monitors the abundance, distribution, and ecological requirements of plant and wildlife species as part of compliance activities and research programs.

The LLNL terrestrial radioactivity monitoring program is designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. All monitoring activities follow U.S. Department of Energy (U.S. DOE) guidance criteria. Monitoring activities on both LLNL sites (the Livermore site and Site 300) and in the vicinity of both sites detect radioactivity released from LLNL that may contribute to radiological dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

Terrestrial pathways from LLNL operations leading to potential radiological dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground-level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see **Chapter 7**) is calculated using a screening model that requires knowledge of radionuclide concentrations in soils, sediments, and surface water.

Surface soil samples are analyzed for plutonium and gamma-emitting radionuclides. Gamma-emitting radionuclides in surface soils include uranium isotopes, which are used to provide data about the natural occurrence of uranium as well as data about the effects of explosive tests at Site 300, some of which contain depleted uranium. Other gamma-emitting, naturally occurring nuclides (potassium-40 and thorium-232) provide additional data about local background conditions. The long-lived fission product cesium-137 provides information about global fallout from historical nuclear weapons testing. In addition, soils at Site 300 are analyzed for beryllium, a potentially toxic metal used there.

Sediments are analyzed for tritium in addition to the same nuclides as surface soils. Concentrations in soil taken from the vadose zone (the region below the land surface where soil pores are only partially filled with water) are compared with de minimis concentrations for tritium and background concentrations for metals. Vegetation and wine samples are measured for tritium alone because tritium is the only nuclide released from LLNL that can be measured in these products. Cosmic radiation accounts for about half the absorbed gamma dose measured by the TLDs; naturally occurring isotopes of the uranium-thorium-actinium decay series provide the dose from natural background radiation found in the earth's crust. By characterizing the background radiation, LLNL can determine what, if any, excess dose can be attributed to Laboratory operations.

Surface soils near the Livermore site and Site 300 have been sampled since 1971. Around the Livermore site, sediments (from selected arroyos and other drainage areas) and vadose zone soils have been sampled since 1988 and 1996, respectively; sampling of sediments or vadose zone soils is not warranted at Site 300. LLNL has monitored tritium in vegetation since 1966 and has performed routine vegetation sampling on and around the Livermore site and Site 300 since 1971. External radiation has been monitored around the Livermore site since 1973 and around Site 300 since 1988.

Sampling for all media is conducted according to written, standardized procedures summarized in Woods (2005).

LLNL also monitors wildlife and plants at the Livermore site and Site 300 and conducts research relevant to the protection of rare plants and animals. Some monitoring and research programs are required by existing permits, while other monitoring programs are designed to track the distribution and abundance of rare species. In addition, baseline surveys are conducted to determine distribution of special status species on LLNL property. Monitoring and research of biota on LLNL property is conducted to ensure compliance with requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and the California Native Plant Protection Act as they pertain to endangered, threatened, and other special status species, their habitats, and designated critical habitats that exist at both LLNL sites.

6.1 Soil and Sediment Monitoring

The number of soil and sediment sampling locations are as follows:

- Livermore site—6 soil, 4 sediment (see **Figure 6-1**)
- Livermore Valley—10 soil, including 3 at the Livermore Water Reclamation Plant (LWRP) (see **Figure 6-2**)
- Site 300—14 soil (see **Figure 6-3**)

The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas with the potential to be affected by LLNL operations. Sampling locations also include areas with known contaminants, such as the LWRP and around explosives testing areas at Site 300.

Surface sediment and vadose zone soil samples are collected from selected arroyos and other drainage areas on and around the Livermore site. These sampling locations, shown in **Figure 6-1,** coincide largely with selected LLNL storm water sampling locations (see **Chapter 5**). Infiltration of natural runoff through arroyo channels is a significant source of groundwater recharge, accounting for an estimated 42% of resupply for the entire Livermore Valley groundwater basin (Thorpe et al. 1990). The collocation of sampling for sediment and storm water runoff facilitates comparison of analytical results.

Surface soil samples are collected from the top 5 centimeters (cm) of soil because aerial deposition is the primary pathway for potential contamination, and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Two 1-meter (m) squares are chosen from which to collect the sample. Each sample is a

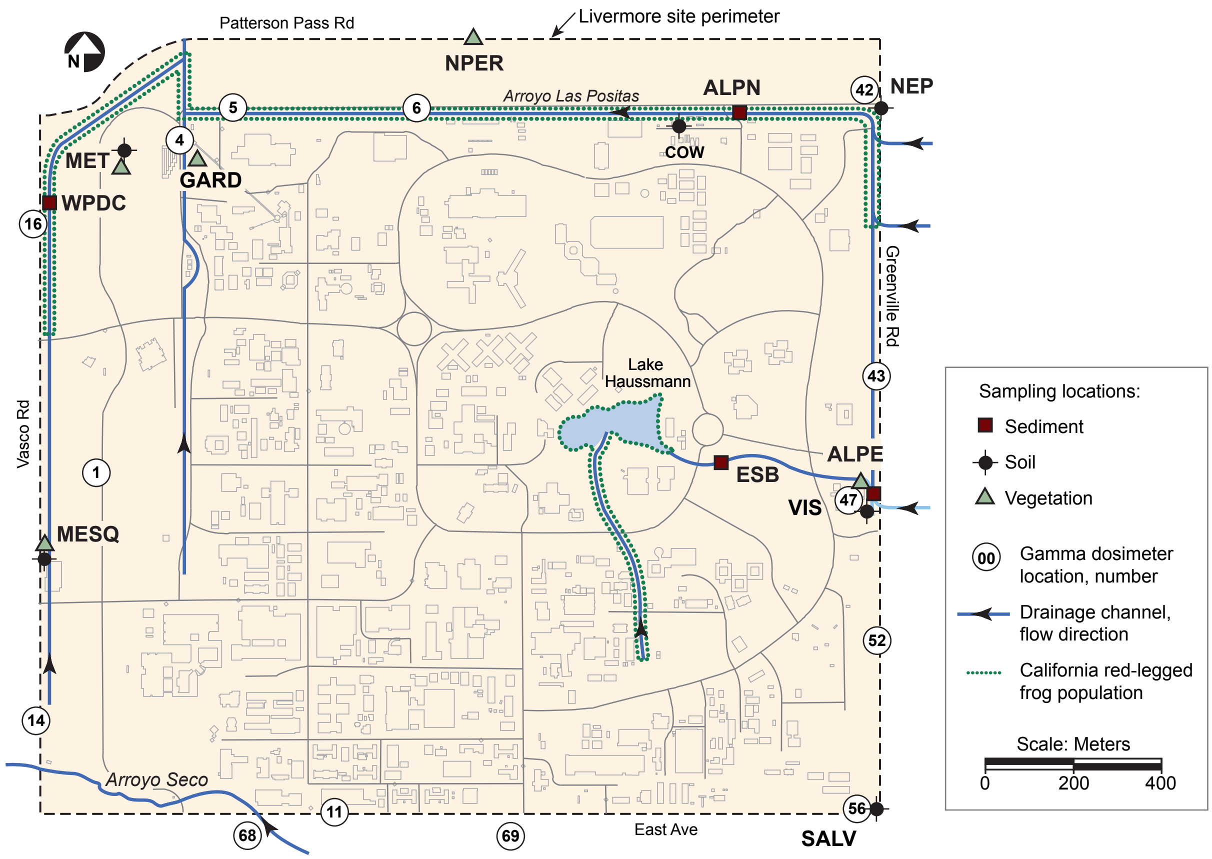

Figure 6-1. Sampling locations and populations of the California red-legged frog, a threatened species, Livermore site, 2006.

composite consisting of 10 subsamples that are collected at the corners and center of each square by an 8.25-cm-diameter, stainless-steel core sampler.

Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along the transect of an arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is taken for tritium analysis; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis. Vadose zone samples are collected at the same location as the tritium subsample. A hand auger is used to collect a 30- to 45-cm deep sample for metals analysis, and an electric drive coring device is used to collect a sample 45- to 65-cm deep for analysis for polychlorinated biphenyls (PCBs).

In 2006, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Annual sediment samples collected at the Livermore site were analyzed for plutonium, gamma-emitting radionuclides, and tritium. Vadose zone samples were analyzed for total and soluble metals; one vadose zone location was analyzed for PCBs.

Prior to radiochemical analysis, surface soil and sediment samples are dried, sieved, ground, and homogenized. The plutonium content of a 100-gram (g) sample aliquot is

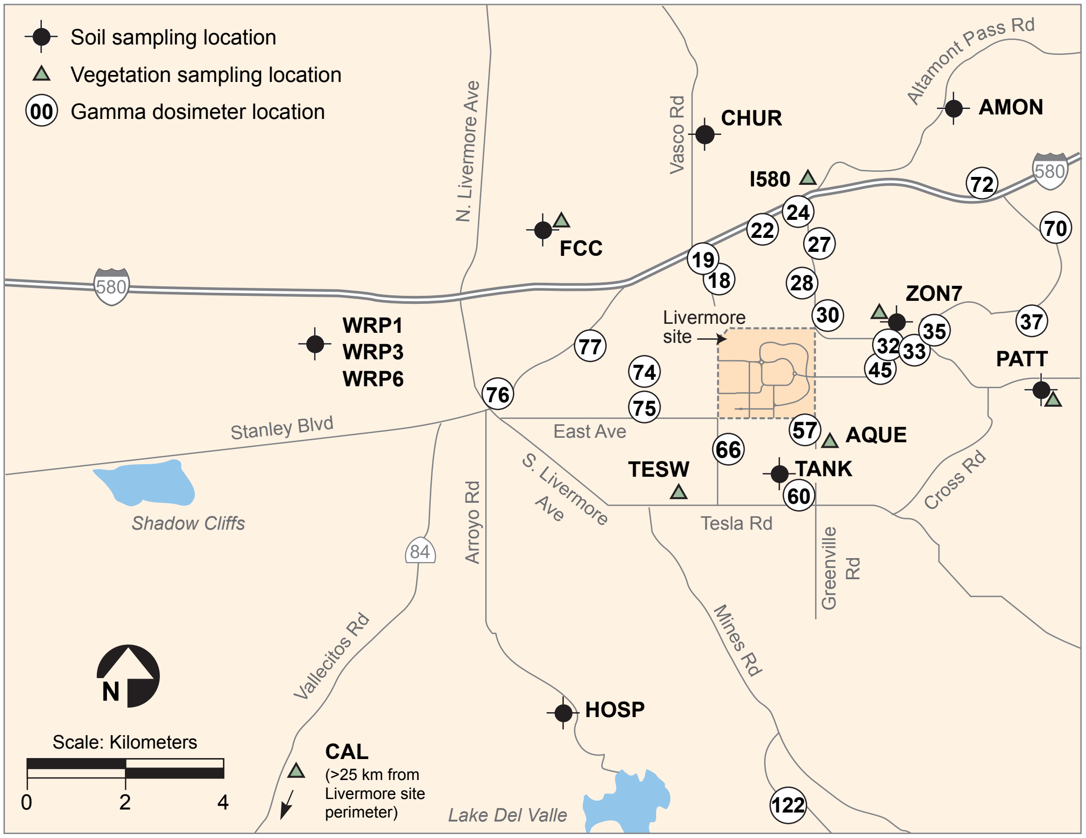

Figure 6-2. Soil and vegetation sampling locations and gamma dosimeter locations, Livermore Valley, 2006.

determined by alpha spectrometry. Other sample aliquots (300 g) are analyzed by gamma spectrometry using a high-purity germanium (HPGe) detector for 47 radionuclides, including fission products, activation products from neutron interactions on steel, actinides, and natural products. For beryllium, 10-g subsamples are analyzed by atomic emission spectrometry.

Vadose zone soil samples are analyzed by standard U.S. Environmental Protection Agency (EPA) methods. Since 2000, a vadose zone soil sample from location ESB (see **Figure 6-1**) has been analyzed for PCBs.

6.1.1 Radiological Monitoring Results

Tables 6-1 through **6-3** present 2006 data on the concentrations of plutonium-238 and plutonium-239+240 in Livermore Valley surface soils and sediments; data for americium-241, which is only detected at LWRP; and data for tritium, which is measured only in surface sediments. Data for cesium-137, potassium-40, thorium-232, uranium-235, and uranium-238 in surface soils from the Livermore Valley sampling locations are provided in **Appendix B**, **Section B.7**.

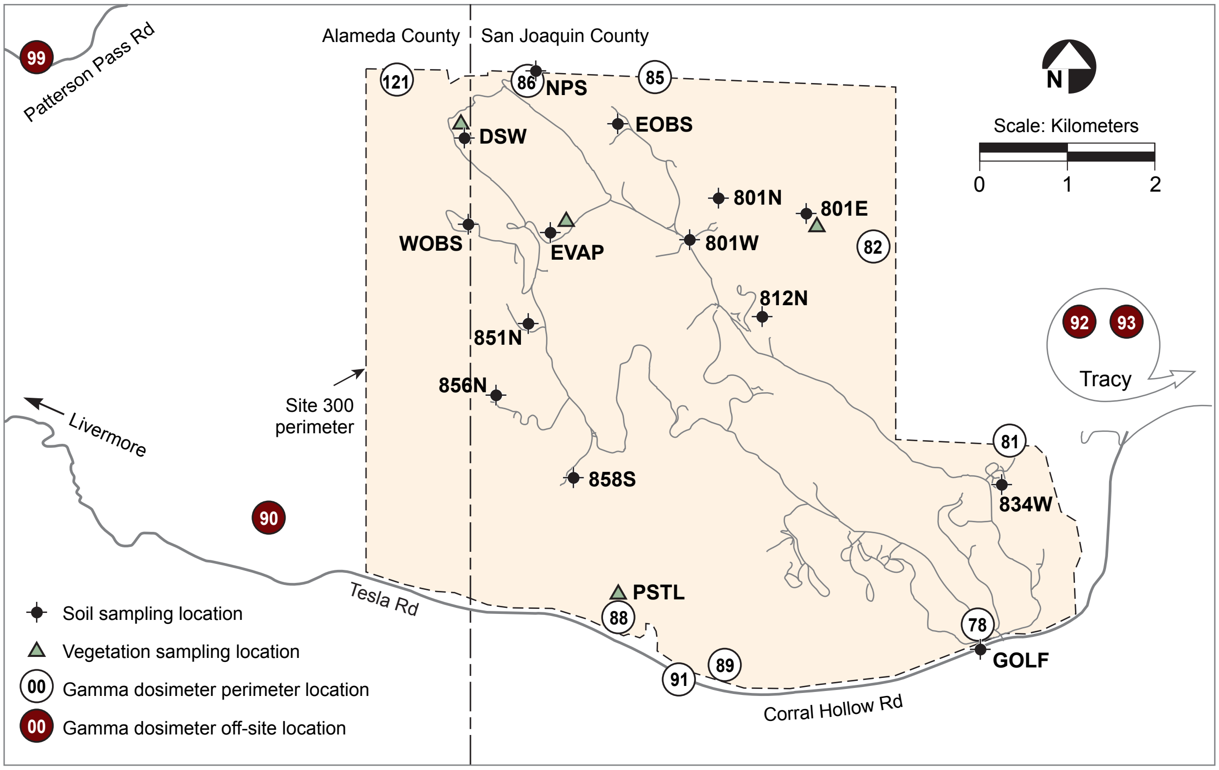

Figure 6-3. Sampling locations at Site 300 and off-site, 2006. Note that in 2006, the vegetation sampling location COHO was replaced by PSTL (at the location of the SW-MEI).

The concentrations and distributions of all observed radionuclides in soil for 2006 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. In the past, plutonium has been detected at levels above background at VIS, a perimeter sampling location near the east boundary of the Livermore site. In 2006, the measured plutonium-239+240 value for VIS was 0.35 millibecquerel (mBq)/dry g (9.5×10^{-3} picocurie [pCi]/dry g), which is less than the 95% upper confidence level for the 95th percentile for background data (i.e., 0.48 mBq/dry g [1.3×10^{-2} pCi/dry g]) (LLNL 1998, Appendix D). The slightly higher values at and near the Livermore site have been attributed to historical operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant of the site. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste.

Sediment sampling at location ESB, which is in the drainage area for the southeast quadrant of the Livermore site, also shows the effects of the historical operation of solar evaporators. The measured value for plutonium-239+240 at this location in 2006 was 1.9 mBq/dry g (5.1×10^{-2} pCi/dry g).

The highest detected value for tritium in 2006 (10 becquerel per liter (Bq/L) [270 pCi/L]) was at location ESB, which is downwind of the Tritium Facility. In 2006, tritium emissions

Table 6-1. Plutonium activity concentrations in Livermore Valley soil, 2006.[(a)]

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)
L-AMON-SO	0.00045 ± 0.0012	0.047 ± 0.0097
L-CHUR-SO	0.0042 ± 0.0020	0.12 ± 0.021
L-COW-SO	0.0013 ± 0.0012	0.033 ± 0.0070
L-FCC-SO	0.0010 ± 0.0012	0.065 ± 0.012
L-HOSP-SO	0.00060 ± 0.0015	0.055 ± 0.011
L-MESQ-SO	0.0021 ± 0.0017	0.022 ± 0.0056
L-MET-SO	0.0027 ± 0.0020	0.047 ± 0.0097
L-NEP-SO	0.0047 ± 0.0025	0.047 ± 0.010
L-PATT-SO	0.00035 ± 0.0012	0.025 ± 0.0060
L-SALV-SO	0.014 ± 0.0043	0.16 ± 0.028
L-TANK-SO	0.0031 ± 0.0019	0.020 ± 0.0053
L-VIS-SO	0.018 ± 0.0049	0.35 ± 0.058
L-ZON7-SO	0.0019 ± 0.0014	0.020 ± 0.0047
Median	0.0021	0.047
Interquartile range	0.0032	0.040
Maximum	0.018	0.35

(a) Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See **Chapter 9**.

were consistent with the Tritium Facility's associated operations, as described in **Chapter 4**. All tritium concentrations were within the range of previous data. LLNL will continue to evaluate tritium in sediment. Elevated levels of plutonium-239+240 resulting from an estimated 1.2×10^9 Bq [32 mCi] plutonium release to the sanitary sewer in 1967 and earlier releases were again detected at LWRP sampling locations in 2006. In addition, americium-241 was detected in one LWRP sample and was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in these historical releases to the sewer.

Figure 6-4 shows the historical (1977 to 2006) median plutonium-239+240 concentrations in surface soils at the LWRP, in the Livermore Valley upwind and downwind of the Livermore site, and at Site 300. Livermore Valley upwind concentrations have remained relatively constant since monitoring began and are generally indicative of worldwide fallout. Downwind concentrations show greater variability than upwind concentrations. In 2006, the downwind locations were VIS, PATT, NEP, COW, AMON, SALV, and ZON7. Notable variability in plutonium-239+240 is also seen in samples from LWRP. Because plutonium-239+240 is likely to be present in discrete particles, the random presence or absence of the particles dominates the measured plutonium-239+240 in any given sample. Plutonium is not used in operations at Site 300; analyses for plutonium in soils were suspended in 1997 given that fallout background was adequately characterized.

Table 6-4 presents data on the concentrations of uranium-235, uranium-238, and beryllium in soil from the Site 300 sampling locations; 2006 soils data for Site 300 for cesium-137, potassium-40, and thorium-232 are provided in **Appendix B**, **Section B.7**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2006 lie within the ranges reported in all years since monitoring began. At 12 of the 14 sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.7%. There is significant uncertainty in calculating the ratio, however, due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. The highest measured values for uranium-235 and uranium-238 and the lowest ratio of uranium-235 to uranium-238 for 2006 occurred at location 812N. The uranium-235 to uranium-238 ratio in this sample equals the

Table 6-2. Plutonium and americium activity concentrations in LWRP soil, 2006.[(a)]

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Americium-241 (mBq/dry g)
L-WRP1-SO	0.31 ± 0.052	6.1 ± 0.97	4.6 ± 1.6
L-WRP3-SO	0.021 ± 0.0049	0.41 ± 0.067	<0.91
L-WRP6-SO	0.11 ± 0.019	2.0 ± 0.32	<0.79
Median	—[(b)]	—[(b)]	—[(b)]
Interquartile range	—[(c)]	—[(c)]	—[(c)]
Maximum	0.31	6.1	4.6

(a) Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See **Chapter 9**.

(b) Median not calculated because of small number of samples.

(c) Interquartile range not calculated because of high incidence of nondetections.

Table 6-3. Plutonium and tritium activity concentrations in surface sediment at four locations on the Livermore site, 2006.[(a)]

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Tritium (Bq/L)
L-ALPE-SD	0.0017 ± 0.0013	0.0069 ± 0.0025	2.5 ± 1.6
L-ALPN-SD	0.00035 ± 0.00091	0.021 ± 0.0050	5.7 ± 1.7
L-ESB-SD	0.16 ± 0.028	1.9 ± 0.30	10 ± 2.6
L-WPDC-SD	0.00067 ± 0.00078	0.0060 ± 0.0021	2.4 ± 1.6
Median	0.0012	0.014	4.1
Interquartile range	—[(b)]	—[(b)]	—[(b)]
Maximum	0.16	1.9	10

(a) Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See **Chapter 9**.

(b) Interquartile range not calculated because of high incidence of nondetections.

ratio for depleted uranium (0.002). Such values at Site 300 result from the use of depleted uranium in explosive experiments.

6.1.2 Nonradiological Monitoring Results

Analytical results for metals are compared with site-specific natural background concentrations for metals. (See **Appendix B**, **Section B.7**, for background concentrations for both the Livermore site and Site 300 and analytical results for metals.)

All metal concentrations at the Livermore site were within site background values with the exception of soluble copper and total and soluble zinc at location ESB. Livermore site

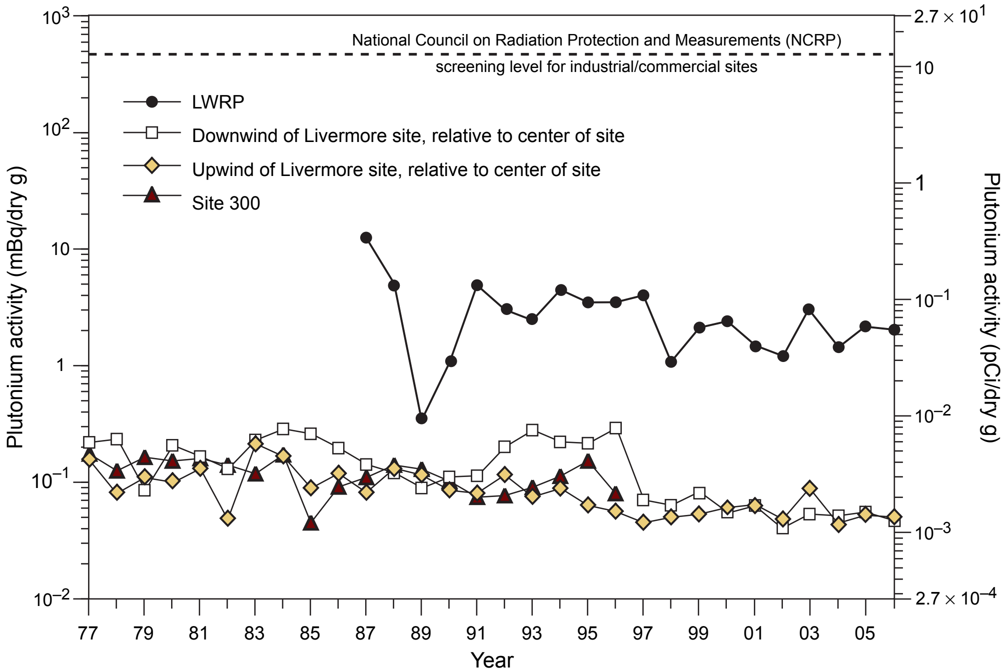

Figure 6-4. Median plutonium-239+240 activities in surface soils at LWRP, downwind and upwind of the Livermore site (1977–2006), and at Site 300 (1977–1997).

groundwater surveillance monitoring (see **Chapter 5**) determines the impact of these metals, if any, on site groundwater.

Aroclor 1260, a PCB, has been detected at location ESB since surveillance for PCBs began at this location in 2000. In 2006, the concentration was 20 milligrams per kilogram (mg/kg). The presence of PCBs suggests residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see **Chapter 5**). The detected concentrations are below the federal and state hazardous waste limits.

Beryllium results for soils at Site 300 (see **Table 6-4**) were within the ranges reported since sampling began in 1991. The highest value, 8.8 mg/kg, was found at B812, which is in an area that has been used for explosives testing. This value is much lower than the 110 mg/kg detected at B812 in 2003. The differing results reflect the particulate nature of the contamination.

6.1.3 Environmental Impact on Soil and Sediment

6.1.3.1 Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2006 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in trace amounts or could not be measured above detection limits.

Table 6-4. Uranium and beryllium concentrations in Site 300 soil, 2006.[a]

Location	Uranium-235[b] (µg/dry g)	Uranium-238[c] (µg/dry g)	Uranium-235/ uranium-238 ratio[d]	Beryllium (mg/kg)
3-801E-SO	0.021 ± 0.013	2.7 ± 2.2	0.0078 ± 0.0080	0.17 (<0.20)[e]
3-801N-SO	0.032 ± 0.0064	7.2 ± 2.2	0.0044 ± 0.0016	0.59
3-801W-SO	0.032 ± 0.0088	4.8 ± 1.2	0.0067 ± 0.0025	<0.20
3-812N-SO	0.29 ± 0.022	130 ± 9.8	0.0022 ± 0.00024	8.8
3-834W-SO	0.021 ± 0.013	1.9 ± 1.1	0.011 ± 0.0094	0.56
3-851N-SO	0.030 ± 0.012	4.5 ± 1.5	0.0067 ± 0.0035	0.62
3-856N-SO	0.026 ± 0.0099	2.1 ± 0.80	0.012 ± 0.0067	0.28
3-858S-SO	0.029 ± 0.015	2.4 ± 1.5	0.012 ± 0.0098	<0.20
3-DSW-SO	0.026 ± 0.013	2.8 ± 1.2	0.0093 ± 0.0061	<0.71
3-EOBS-SO	0.021 ± 0.012	2.5 ± 1.1	0.0084 ± 0.0061	0.19 (<0.20)[e]
3-EVAP-SO	0.037 ± 0.0075	4.1 ± 1.4	0.0090 ± 0.0036	0.21
3-GOLF-SO	0.025 ± 0.0068	2.1 ± 1.7	0.012 ± 0.010	0.27
3-NPS-SO	0.020 ± 0.0087	2.6 ± 2.1	0.0077 ± 0.0071	0.070 (<0.20)[e]
3-WOBS-SO	0.016 ± 0.010	1.5 ± 0.96	0.011 ± 0.0095	<0.20
Median	0.026	2.7	0.0087	<0.24
Interquartile range	0.010	2.2	0.0040	—[f]
Maximum	0.29	130	0.012	8.8

(a) Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See **Chapter 9**.

(b) Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by specific activity of uranium-235 (i.e., 0.080 Bq/µg or 2.15 pCi/µg).

(c) Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by specific activity of uranium-238 (i.e., 0.01245 Bq/µg or 0.3367 pCi/µg).

(d) Ratio of uranium-235 to uranium-238 is 0.00725 for naturally occurring uranium and 0.002 for depleted uranium.

(e) Nondetections of nonradioactive constituents are shown as less than (<) the reporting limit (RL) for that analysis. If the analytical laboratory provided an estimated analytical result above the method detection limit and less than the reporting limit, that result is shown followed by the reporting limit in parentheses.

(f) Interquartile range not calculated because of high incidence of nondetections.

The highest value for plutonium-239+240 in 2006 (6.1 mBq/dry g [0.16 pCi/dry g]), measured at LWRP, is 1.3% of the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999). Regression analysis of the annual medians of the upwind and downwind data groups shows a slight decrease in plutonium-239+240 values over time.

LLNL has investigated the presence of radionuclides in local soils frequently over the years; the studies have consistently shown that the concentrations of radionuclides in local

Table 6-5. Selected studies of radionuclides in local soils, 1971 to 2003.

Year	Study	Reference
1971–1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972, 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1976	Evaluation of the Use of Sludge Containing Plutonium as a Soil Conditioner for Food Crops	Myers et al. 1976
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historical data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995
1999	Summary of results of 1998 sampling at Big Trees Park	Gallegos et al. 1999
2000	Health Consultation, Lawrence Livermore National Laboratory, Big Trees Park 1998 Sampling	ATSDR 2000
2002	Livermore Big Trees Park:1998 Results	MacQueen et al. 2002
2003	ATSDR Public Health Assessment Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community	ATSDR 2003

soils are below levels of health concern. Selected LLNL studies, as well as studies by other agencies, are listed in **Table 6-5**.

6.1.3.2 Site 300

The concentrations of radionuclides and beryllium detected in soil samples collected at Site 300 in 2006 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occurred near the firing tables at Buildings 801 and 812. They result from the fraction of the firing table operations that disperse depleted uranium. The uranium-238 concentrations are below the NCRP-recommended screening level for commercial sites (313 µg/g [3.9 Bq/g or 105 pCi/g]). Historically, some measured concentrations of uranium-238 near Building 812 (location 812N) have been greater than the screening level. A Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial investigation has been completed at the Building 812 firing table area, which defines the nature and extent of contamination (see **Chapter 8**).

6.2 Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (see **Figure 6-1**) and in the Livermore Valley (see **Figure 6-2**) are divided for comparison into the following three groups:

- Near locations (AQUE, GARD, MESQ, NPER, MET, and VIS) are on site or less than 1 kilometer (km) from the Livermore site perimeter.
- Intermediate locations (I580, PATT, TESW, and ZON7) are in the Livermore Valley and 1 to 5 km from the Livermore site perimeter.
- Far locations (FCC, CAL) are more than 5 km from the Livermore site perimeter; FCC is about 5 km away and generally upwind and CAL is more than 25 km away.

Tritium from LLNL operations may be detected at the Near and Intermediate locations depending on wind direction and magnitude of the releases. Far locations are highly unlikely to be affected by LLNL operations.

Site 300 has four monitoring locations for vegetation (PSTL, 801E, DSW, and EVAP). See **Figure 6-3**. Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to occasional uptake of contaminated groundwater by the roots. The highest concentrations observed in the past ten years (5140 Bq/L [13,900 pCi/L] at EVAP and 3330 Bq/L [90,000 pCi/L] at DSW) occurred in 1998. At the other two locations, 801E and PSTL,[a] the only likely potential source of tritium uptake is the atmosphere, although groundwater in the vicinity of PSTL is contaminated with low levels of tritium.

Wines for sampling in 2006 were purchased from supermarkets in Livermore. The wines represent the Livermore Valley, two other regions of California, and the Rhone Valley in France.

Water is extracted from vegetation by freeze-drying and counted for tritiated water (HTO) using liquid scintillation techniques. Between 1991 and 2005, wine samples were analyzed directly using helium-3 mass spectrometry, an extremely sensitive and costly method that analyzes for both HTO and OBT. Wines purchased in 2006 were prepared for sampling using a method under development that separates the water fraction from the other components of the wine, including the OBT, so that samples can be counted using an ultra-low-level scintillation counter.

6.2.1 Vegetation Monitoring Results

Concentrations of tritium in vegetation based on samples taken at the Livermore site, in the Livermore Valley, and Site 300 in 2006 are shown in **Table 6-6**. The highest mean tritium concentration for 2006 was at the Near location VIS, which is downwind of the Livermore site.

(a) Because accessing sampling location COHO (in use since 2001) was becoming increasingly difficult, vegetation sampling was moved to location PSTL, close to the location of the SW-MEI for Site 300 (see **Chapter 7**).

Table 6 6. Quarterly, median, and mean concentrations of tritium in plant water for the Livermore site Livermore Valley, and Site 300, and mean annual ingestion doses, 2006.[(a)]

Sampling locations		Concentration of tritium in plant water (in Bq/L)						Mean annual ingestion dose[(b)] (in nSv/yr)
		First quarter	Second quarter	Third quarter	Fourth quarter	Median	Mean	
NEAR (on site or <1 km from Livermore site perimeter)	AQUE	2.2 ± 1.6	4.8 ± 1.6	0.85 ± 1.8	4.1 ± 1.7	3.2	3.0	15
	GARD	1.6 ± 1.6	4.7 ± 1.6	0.084 ± 1.8	3.1 ± 1.7	2.4	2.4	12
	MESQ	1.6 ± 1.6	4.2 ± 1.6	1.4 ± 1.8	0.60 ± 1.6	1.5	2.0	10
	MET	1.4 ± 1.6	2.3 ± 1.5	1.3 ± 1.8	5.3 ± 1.7	1.8	2.6	13
	NPER	2.5 ± 1.6	2.4 ± 1.5	2.4 ± 1.9	3.5 ± 1.7	2.4	2.7	13
	VIS	1.0 ± 1.6	3.4 ± 1.5	2.1 ± 1.9	11 ± 1.8	2.8	4.4	22
INTERMEDIATE (1–5 km from Livermore site perimeter)	I580	–0.12 ± 1.5	2.1 ± 1.5	–0.32 ± 1.8	2.2 ± 1.6	0.99	0.97	<10[(c)]
	PATT	–0.25 ± 1.5	1.3 ± 1.4	1.0 ± 1.8	0.16 ± 1.5	0.58	0.55	<10[(c)]
	TESW	–0.054 ± 1.5	1.7 ± 1.5	1.4 ± 1.8	1.4 ± 1.6	1.4	1.1	<10[(c)]
	ZON7	0.91 ± 1.6	2.3 ± 1.5	1.5 ± 1.8	1.5 ± 1.6	1.5	1.6	<10[(c)]
FAR (>5 km from Livermore site perimeter)	CAL	0.80 ± 1.5	1.6 ± 1.5	0.061 ± 1.8	–0.17 ± 1.5	0.43	0.57	<10[(c)]
	FCC	–0.70 ± 1.5	1.7 ± 1.5	0.091 ± 1.8	0.092 ± 1.5	0.092	0.30	<10[(c)]
Site 300	PSTL	3.1 ± 1.7	1.9 ± 1.5	0.81 ± 1.8	0.20 ± 1.5	1.4	1.5	[(d)]
	801E	3.7 ± 1.7	4.3 ± 1.6	–1.1 ± 1.7	–0.27 ± 1.5	1.7	1.7	[(d)]
	DSW[(e)]	4.2 ± 1.8	9.4 ± 1.8	59 ± 3.3	860 ± 11	34	230	[(d)]
	EVAP[(e)]	0.39 ± 1.5	13 ± 1.9	0.037 ± 1.8	10 ± 1.9	5.2	5.9	[(d)]

(a) Radioactivities are reported as the measured concentration and an uncertainty (±2σ counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection. See **Chapter 9**.

(b) Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 7-6**.

(c) When concentrations are less than the detection limit (about 2.0 Bq/L), doses can only be estimated as being less than the dose at that concentration.

(d) Dose is not calculated because there is no pathway to dose to the public from vegetation at Site 300.

(e) Plants at these locations are rooted in areas of known subsurface contamination.

Median concentrations of tritium in vegetation at sampling locations at the Livermore site and in the Livermore Valley have decreased noticeably since 1989 (see **Figure 6-5**). Median concentrations at the Far and Intermediate locations have been below detection limits for several years. Between 2003 and 2005, the median concentrations at Near locations were below detection limits, and, in 2006, the median concentration at Near locations, 2.4 Bq/L (65 pCi/L), was just above the detection limit. The lower limit of detection (LLD) of scintillation counting has varied over the years. A comparison of results based on the recent mean value of the LLD of about 2.0 Bq/L (54 pCi/L) eliminates some variability arising from uncertain counting statistics at these low levels. The highest concentration in plant water from Near locations in 2006 was just 1.5% of the drinking water MCL (740 Bq/L [20,000 pCi/L]).

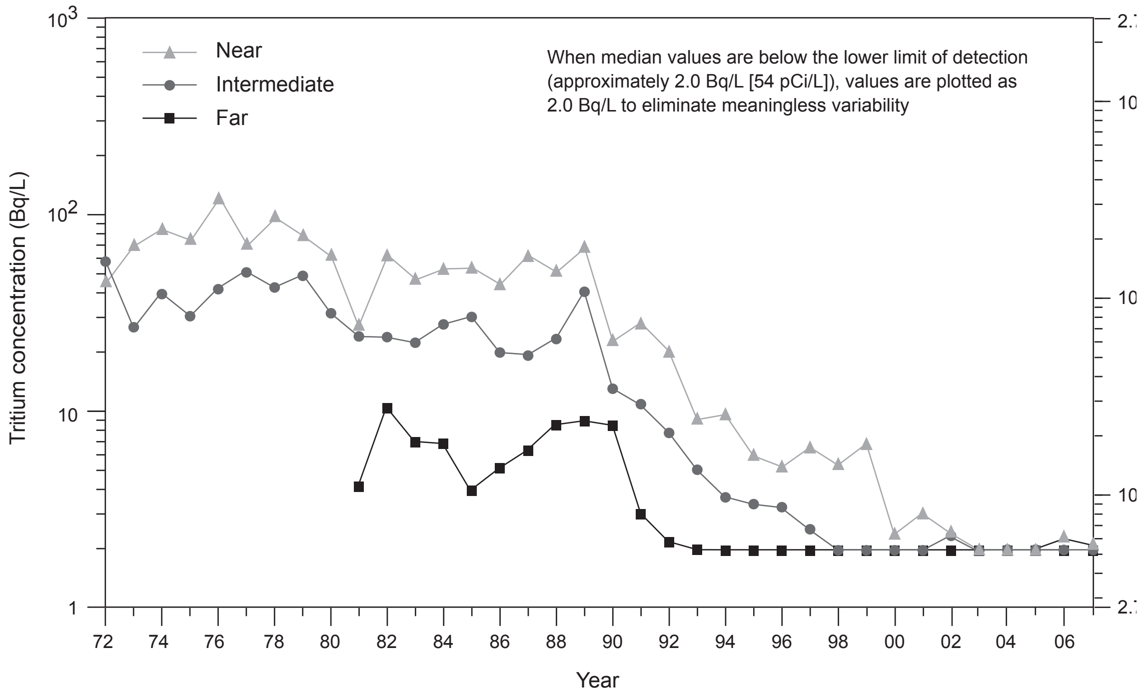

Figure 6-5. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2006.

At Site 300, the median concentration at location 801E was below detection limits, as it has been since 1991. The median concentration at location PSTL was also below detection limits. Tritium concentrations in vegetation at locations DSW and EVAP have been erratic since 1983, with concentrations being either high or below the LLD, depending upon whether the roots were taking up contaminated groundwater. The highest concentration (860 Bq/L [23,220 pCi/L]) was observed at DSW.

6.2.2 Wine Monitoring Results

Analysis of the wines sampled in 2006 demonstrates the same relationship between the Livermore Valley, California (other than the Livermore Valley), and the Rhone Valley (France) wines that has been seen routinely in the past. Concentrations of tritium in California wines are low and reflect residual historical bomb fallout and cosmogenic tritium levels; concentrations in Livermore Valley wines range from the low levels seen in California wines to the higher levels seen in Rhone Valley wines; and the concentration in one of the Rhone Valley wines is higher than any of the Livermore Valley wines (see **Table 6-7**). The highest concentration in a Livermore Valley wine sampled in 2006 (5.0 Bq/L [135 pCi/L]) was from a wine made from grapes harvested in 2002.

The Livermore Valley wines purchased in 2006 represent vintages from 2002 to 2004. Tritium concentrations must be decay-corrected to the year of harvest to correlate with tritium concentrations in air and soil to which the grape was exposed. The correlation between decay-corrected concentrations and annual tritium releases from the Livermore site has never been a strong one. Concentrations for the sampled wines show the same relationships after they have been corrected for radiological decay. In 2006, decay-corrected concentrations for Livermore Valley wine samples ranged from 1.2 to 6.4 Bq/L; for the two California wine samples, 1.2 and 2.1 Bq/L; and for the two Rhone Valley wine samples, 3.0 and 7.7 Bq/L.

6.2.3 Environmental Impact on Vegetation and Wine

6.2.3.1 Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-6**. These hypothetical doses, from ingestion of HTO in vegetables, milk, and meat, were calculated from annual mean measured concentrations of HTO in vegetation using the transfer factors from **Table 7-6** (**Chapter 7**) based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). The hypothetical annual ingestion dose, based on the highest observed mean HTO concentration in vegetation for 2006, was 22 nanosieverts (nSv) (2.2 microrems [μrem]), which is slightly less than the highest dose estimated in 2005.

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to a panel of tritium experts, "the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this" (ATSDR 2002, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2006, including OBT, is 44 nSv/year (yr) (4.4 μrem/yr). This maximum dose is about 1/68,000 of the average annual background dose in the United States from all natural sources and about 1/230 the dose from a panoramic dental x-ray. Because it is based on highly conservative assumptions, this already extremely low dose is still considerably higher than any likely potential dose received.

During 2006 at Site 300, no tritium was released to the atmosphere from LLNL operations. Consequently, vegetation concentrations were near or below detection limits except at locations of contaminated groundwater (see **Chapter 8**, **Section 8.2.3**). Groundwater contaminated by past activities affects concentrations in vegetation

Table 6-7. Tritium in retail wine, 2006[a,b]

	Concentration (in Bq/L) by area of production		
Sample	Livermore Valley	California	Europe
1	0.95 ± 0.64	1.0 ± 0.64	2.6 ± 0.65
2	1.5 ± 0.63	1.8 ± 0.63	6.7 ± 0.95
3	1.8 ± 0.63		
4	2.3 ± 0.64		
5	2.7 ± 0.65		
6	5.0 ± 0.80		
Dose (nSv/yr)[c]	6.1	2.2	8.1

(a) Radioactivities are reported here as the measured concentration and an uncertainty (±2σ counting error).

(b) Wines from a variety of vintages were purchased and analyzed for the 2006 sampling. Concentrations are those on May 17, 2007.

(c) Calculated based on consumption of 52 L wine per year at maximum concentration (see **Chapter 7**). Doses account for contribution of organically bound tritium (OBT) as well as of HTO.

at locations DSW and EVAP. However, the dose does not need to be calculated from these elevated concentrations because neither people nor livestock ingest vegetation at Site 300.

6.2.3.2 Wine

For Livermore Valley wines purchased in 2006, the highest concentration of tritium (5.0 Bq/L [135 pCi/L]) was just 0.68% of the EPA's standard for maximal permissible level of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking one liter per day of the Livermore Valley wine with the highest concentration purchased in 2006 would have resulted in a dose of 43 nSv/yr (4.3 µrem/yr). A more realistic dose estimate, based on moderate drinking (one liter per week)[a] at the mean of the Livermore Valley wine concentrations (2.4 Bq/L [65 pCi/L]) would have been 2.9 nSv/yr (0.29 µrem/yr). Both doses explicitly account for the added contribution of OBT.[b]

The potential dose from drinking Livermore Valley wines in 2006, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/310 of a single dose from a panoramic dental x-ray.

6.3 Ambient Radiation Monitoring

Gamma radiation in the environment has two natural sources—terrestrial and cosmic. The terrestrial source is the result of the radioactive decay of parent elements formed in the earth's crust 4.5 billion years ago (e.g., uranium-238, thorium-232, and potassium-40) and their daughter radiations. The other source is cosmic radiation, which induces secondary radiations from interactions with atmospheric nuclei in the upper atmosphere. The cosmic interactions produce meson, neutron, gamma, and electron radiations at the earth's surface (Eisenbud 1987).

LLNL's ambient radiation monitoring program is designed to distinguish naturally occurring gamma radiation from any ambient radiation that is the result of LLNL operations by sampling at enough locations to validate the large variance in the natural background from season to season and by location.

6.3.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. The roentgen (R) was adopted as the special unit of

(a) Moderate consumption is higher than the average consumption of wine in California (15.7 L/yr) (Avalos 2005).

(b) Dose from wine was calculated based on the measured concentration of HTO multiplied by 1.3 to account for the potential contribution of OBT that was removed so that the tritium in wine could be counted using liquid scintillation counting. Dose coefficients for HTO and OBT are those of the International Commission on Radiological Protection (1996).

exposure dose by the International Commission on Radiological Units in 1956 and is defined as the charge required to ionize a given volume of air (2.58×10^{-4} coulombs per kilogram of air) (Attix and Roesch 1968).

It is this equivalency that is used to determine the quantity of ambient radiation measured by thermoluminescent dosimeters (TLDs) placed in the community surrounding LLNL. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thallium-activated calcium sulfate ($CaSO_4$), to measure environmental gamma dose.

As a TLD absorbs ionizing energy, electron–hole pairs are created in the crystal lattice, trapping this absorbed energy in the crystal's excited state. The absorbed energy in the TLD crystal is released in the form of light emission upon heating the TLD to extreme temperature. This light emission, which is proportional to the TLD absorbed dose, is then collected by a photomultiplier tube and compared to its glow curve (is heated, releasing the trapped energy), which is calibrated to a known standard of cesium-137 gamma energy of 662 kilo-electronvolts (keV). The result of the TLD exposure is then reported in the Système International (SI) unit of sievert (Sv) from the calculated dose in mR (1×10^{-3} R).

To compare LLNL dose contributions with the natural background, the analysis is divided into three groups:

- comparison of the average quarterly dose (mSv) for the Livermore site, Livermore Valley, and Site 300 locations for the five-year period from 2002 to 2006
- comparison of the average quarterly dose (mSv) for the Livermore site and Livermore Valley locations in 2006
- comparison of average quarterly dose (mSv) for Site 300, city of Tracy, and Site 300 vicinity in 2006

As shown in **Figure 6-6,** these comparisons are made.

As policy, the State of California Radiological Health Branch maintains several collocated TLD sample sites around the LLNL perimeter and Livermore Valley for independent monitoring comparison.

To obtain a true representation of local site exposure and determine any dose contribution from LLNL operations, an annual environmental monitoring compliance assessment is done in accordance with DOE Order 450.1, Environmental Protection Program, through a quarterly deployment cycle. TLDs are deployed at a height of 1 m, adhering to the guidance of *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991).

For the purpose of reporting comparisons, data are reported as a "standard 90-day quarter" with the dose reported in millisievert (mSv; 1 mSv = 100 mrem).

6.3.2 Monitoring Results

Figure 6-6 represents the average quarterly dose (in mSv) for the recent five-year period for the Livermore site perimeter, Livermore Valley and Site 300. Tabular data for each sampling

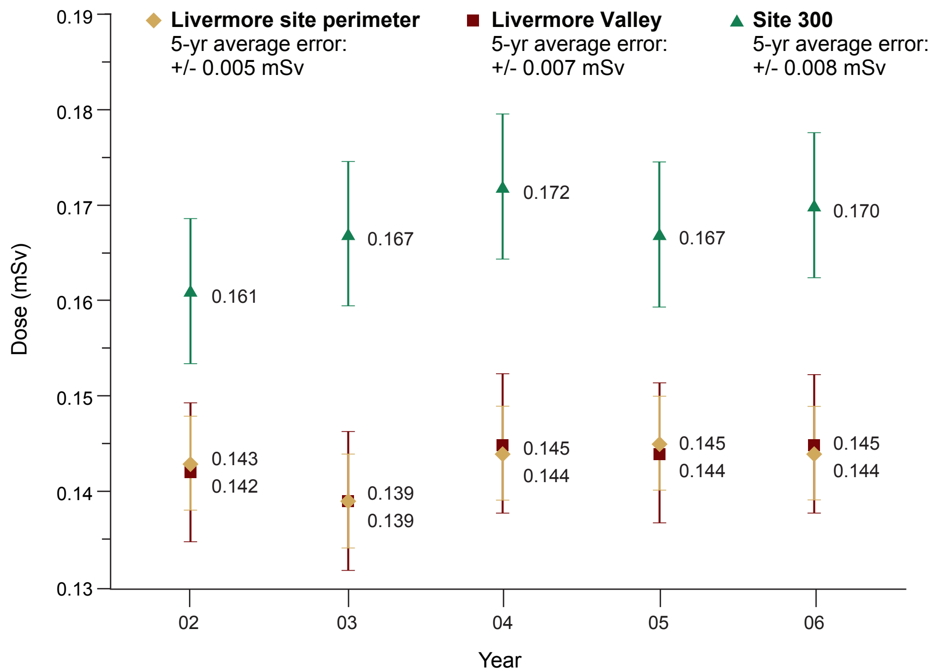

Figure 6-6. Comparison of the average quarterly dose for the Livermore site, Livermore Valley, and Site 300 monitoring locations from 2002 to 2006.

location are provided in **Appendix B**, **Section B.7**. Missing data are due to lost or damaged samples and are noted in these tables.

From year to year, the exposure of a TLD at any particular sampling location changes very little. Local variation of the Livermore site perimeter (see **Figure 6-6**) is due largely to changes in the local distribution of the radon flux and natural soil variability in the abundance of uranium and thorium, which produce gamma decay products for the given series on some small level and from changes in the cosmic radiation flux. Similar variability is seen within the other location groups. The difference in the doses at the Livermore site perimeter, Livermore Valley, and Site 300 can be attributed directly to the difference in the geological substrates. The Neroly Formation in the region around Site 300 has higher levels of naturally occurring uranium, which provides the higher concentration of thorium found in the soil data.

6.3.3 Environmental Impact from Laboratory Operations

The data do not suggest any environmental impact or increase in ambient radiation levels surrounding the Livermore site, Livermore Valley, or Site 300 as a direct result of LLNL operations for 2006. Radiation dose trends remain consistent with annual average levels for each sample location. As depicted in **Figure 6-6**, the annual average gamma radiation dose for the LLNL site perimeter and the Livermore Valley from 2002 to 2006 are statistically equivalent and show no discernible impact due to operations conducted at LLNL.

6.4 Special Status Wildlife and Plants

Special status wildlife and plant monitoring at LLNL is focused on species considered to be rare, threatened, and endangered, including species listed under the federal or California Endangered Species Acts; species considered of concern by the California Department of Fish and Game and the U.S. Fish and Wildlife Services (USFWS); and species that require inclusion in National Environmental Policy Act (NEPA) and California Environmental Quality Act of 1970 (CEQA) documents.

Five species that are listed under the federal or California Endangered Species Acts are known to occur at Site 300—the California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus)*, Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*) at Site 300, this species is known to have occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. California threatened Swainson's Hawks (*Buteo swainsoni*) and California-endangered Willow Flycatchers (*Empidonax traillii*) have been observed at Site 300, but breeding habitat for these species does not occur at Site 300. The California red-legged frog is also known to occur at the Livermore site (see **Figure 6-1**).

Several species that are considered rare or otherwise of special interest by the federal and California state governments also occur at the Livermore site and Site 300. These species include California species of special concern, California fully protected species, federal species of concern, species that are the subject of the federal Migratory Bird Treaty Act, and species included in the California Native Plant Society's (CNPS's) *Inventory of Rare and Endangered Plants in California* (CNPS 2001).

Known observations of these five listed species and two California species of special concern (Burrowing Owl and Tricolored Blackbird) are shown in **Figure 6-7**. Vertebrate species and rare invertebrate species known to occur at Site 300, including state and federally listed species and other species of special concern are listed in **Appendix E**. A similar list has not been prepared for the Livermore site.

Including the federally endangered large-flowered fiddleneck, four rare plant species and four uncommon plant species are known to occur at Site 300. Three of the rare species—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), and the diamond-petaled poppy (*Eschscholzia rhombipetala*)—are included in the CNPS List 1B (CNPS 2001). These species are considered rare and endangered throughout their range. The fourth rare species, the round-leaved filaree (*Erodium macrophyllum*), is currently included on CNPS List 2 (CNPS 2001). This list includes species

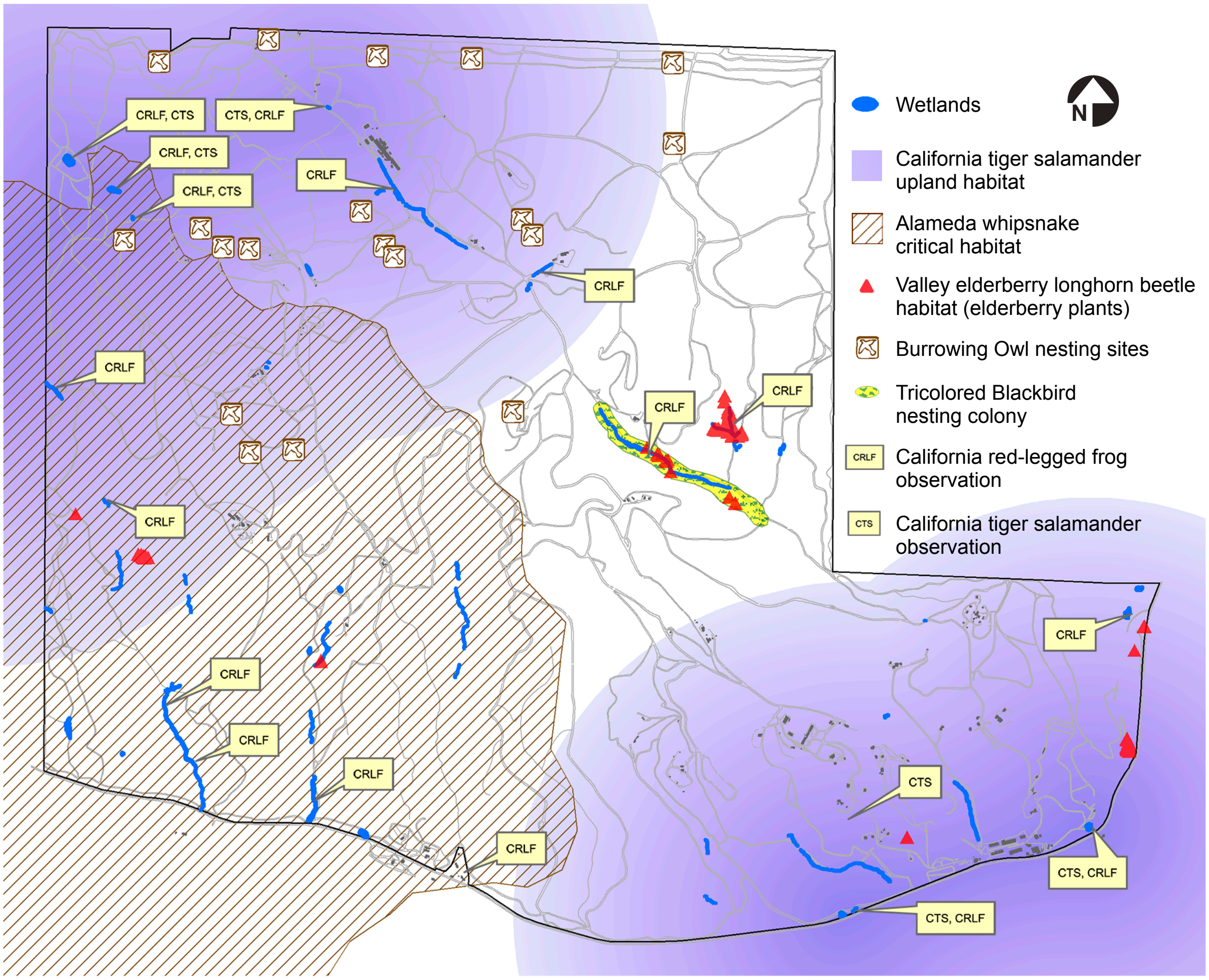

Figure 6-7. Distribution of special status wildlife, Site 300, 2006.

that are rare or endangered in California and elsewhere. The location of these four rare plant species on Site 300 is shown in **Figure 6-8**.

The four uncommon plant species—the gypsum-loving larkspur (*Delphinium gypsophilum* subsp. *gypsophilum*), California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*)—are all included on the CNPS List 4 (CNPS 2001). List 4 plants are uncommon enough to warrant monitoring but are not considered rare. Past surveys have failed to identify any rare plants on the Livermore site (Preston 1997, 2002).

The following sections describe results from LLNL special status wildlife and plant studies and surveys. For an estimate of LLNL's dose to biota, see **Chapter 7, Section 7.6**.

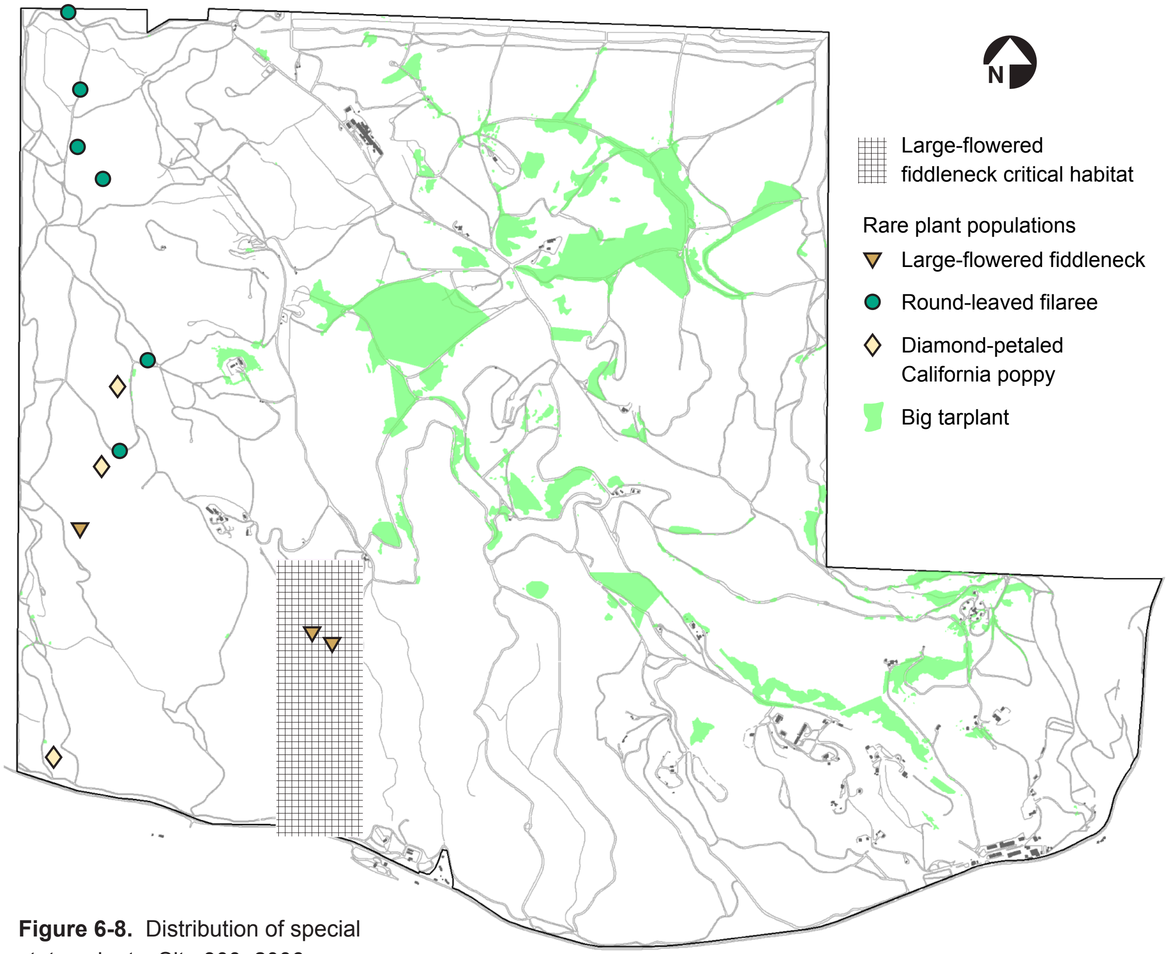

Figure 6-8. Distribution of special status plants, Site 300, 2006.

6.4.1 Compliance Activities

6.4.1.1 Arroyo Seco

In June of 2005, the USFWS issued a biological opinion to DOE/National Nuclear Security Administration (NNSA) for the Arroyo Seco Management Plan. The biological opinion considered potential impacts to the California red-legged frog and the California tiger salamander.

The Arroyo Seco Management Plan was completed during the 2005 dry season. The project included repairs to gully erosion around storm drain outfalls, installation of vegetated geogrids in eroding transition zones between existing gabion baskets and neighboring banks, and the addition of drop inlet structures to convey concentrated runoff down bank slopes at other gully erosion sites. In addition, the lower third of the Livermore site reach of the arroyo was realigned to increase the amount of meander in this area and decrease the slope of the creek banks. This involved constructing a new low flow channel and right and left in-channel terraces, and planting the channel terraces and bank slopes with native trees and shrubs.

The first year of the five-year plan for monitoring the restoration of this site was conducted in 2006, as required by the Army Corps of Engineers permit for this project. Monitoring includes annually measuring the survivorship of plants that were installed as part of the restoration and estimating the percent cover of grasses and forbs, shrubs, and trees at the project site. In most portions of the project site, the percent cover of grasses and forbs was above the expected success criteria for year one (2006). On the terrace on the north side of the arroyo, the percent cover of grasses and forbs was 20%, which is 10% lower than the success criteria for year one (30%). The observed percent cover for shrubs met the success criteria of 5% in all areas. The percent cover of trees in both the south bank and terrace met the success criteria of 5%. The percent cover of trees on the north bank and terrace was less than the required 5%. To help correct deviations from the success criteria described above, approximately 145 plants were installed at the site in the winter of 2006/2007 to replace plants that did not survive the previous year, and additional measures were taken to control weeds at the site.

6.4.1.2 Habitat Enhancement Project

Prior to 2005, artificial wetlands had been maintained at Buildings 865, 851, 827, and 801 (Site 300) as a result of water discharge from cooling towers and potable water discharges. In 2005, water discharges were terminated at these locations.

In late August 2005, a habitat enhancement project was implemented at Site 300 in accordance with a 2002 biological opinion to compensate for habitat value loss from these artificial wetlands. Two areas within the Mid-Elk Ravine drainage were enlarged and deepened to create habitat pools where California red-legged frogs are known to occur and where pooling water features were limited in extent. The three primary goals of this effort were the creation of open water habitat (minimum of 0.005 hectares [ha] [0.012 acres (ac)]), the protection of 0.75 ha (1.86 ac) of wetland and upland habitat, and the translocation of California red-legged frogs from the Building 865 wetland to the two new pools. In 2005, the first two goals were accomplished. The translocation of the California red-legged frog was conducted in February and March of 2006.

6.4.1.3 Oasis and Round Valley Culvert Replacement Projects

In 2006, culvert replacement projects were completed at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails cross an intermittent drainage in Draney Canyon. The Oasis project resulted in impacts to an estimated 0.047 ha (0.115 ac) of jurisdictional waters as defined by the Army Corps of Engineers. The Round Valley project included the creation of a 0.089-ha (0.22-ac) pool upstream of the fire trail crossing and culvert replacement site in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for amphibian species on site. In particular, it is hoped that the pool will be used by California red-legged frogs and California tiger salamanders. These projects were completed under the biological opinion for maintenance and operations of Site 300.

A temporary pool was created adjacent to the Oasis project site as a temporary refuge for California red-legged frogs that were captured within the construction area. After the completion of this project, California red-legged frogs were released from the temporary pool and allowed to recolonize the project site.

The Round Valley project was completed when the project site was dry and no water was present in the drainage at the project site, and no California red-legged frogs or California tiger salamanders were observed at the site during construction. As a result, it was not necessary to temporarily relocate any California red-legged frogs at the Round Valley location.

6.4.1.4 Surface Impoundment Closure and Mitigation Site

During the summer of 2005, closure of the Class II wastewater surface impoundments at Site 300 was executed. In the past, these impoundments had received rinse water from high explosives and photo processing activities and were now reaching the end of their service lifespan. Mitigation for the removal of the artificial impoundments was required because California tiger salamanders had been observed in the impoundments during site-wide amphibian surveys in the winter of 1996 and 1997. Under a biological opinion from the U.S. Fish and Wildlife Service, LLNL was to conduct searches for tiger salamanders returning to the area during the winter of 2006 (the season following the basin removal) and translocate these individuals to a mitigation site in the northwest corner of the property. The mitigation site was an enhanced seasonal pool that lacked sufficient depth as a successful salamander breeding site.

No California tiger salamanders were captured in the winter and spring of 2006 returning to the previous impoundment area; therefore, no salamander translocations were performed. The California tiger salamander mitigation pond, however, was colonized by California tiger salamanders that had already occurred in the area. Eggs, larvae, and newly metamorphosed individuals were recorded at the mitigation pool site in the spring and summer of 2006.

6.4.2 Invasive Species Control Activities

Invasive species, including the bullfrog *(Rana catesbeiana)* and the largemouth bass *(Micropterus salmoides),* are a significant threat to the California red-legged frog at the Livermore site. Feral pigs (*Sus scrofa*) are an exotic species that are now present at Site 300. These formidable predators threaten the survival of this protected frog and other native species. They will prey on the California red-legged frog's eggs and tadpoles and usually compete with California red-legged frogs for food and other resources. Control of these invasive species is necessary to ensure the survival of California red-legged frogs at the Livermore site and Site 300. In addition, prevention of the downstream dissemination of invasive species is important to protect other local and regional native species populations relative to the Livermore Valley watershed.

6.4.2.1 Drainage of Lake Haussmann to Control Bullfrogs

Lake Haussmann (previously Drainage Retention Basin) was drained in 2000 and 2001 in an effort to eliminate bullfrog larvae. The habitat enhancement pool portion of Lake Haussmann and the Livermore site reach of Arroyo Las Positas were drained to control bullfrogs and largemouth bass in the fall of each year from 2002 through 2005. Adult bullfrogs and egg masses were also removed from Lake Haussmann during the bullfrog's breeding season (late spring to early fall each year between 2002 and 2006). One nighttime survey for adult bullfrogs was conducted in Lake Haussmann in the summer of 2006. During this survey, bullfrogs were identified by a qualified biologist and removed. In addition, two bullfrog egg masses were removed from Lake Haussmann during weekly surveys in 2006. In 2005, 14 bullfrog egg masses were removed from Lake Haussmann. These invasive species control measures were conducted under the 2002 amendment to the Arroyo Las Positas Maintenance Plan biological opinion.

Monitoring of the Mid-Elk Ravine enhancement pools in 2006 resulted in observations of colonization, breeding, egg-laying, larvae development, and young of the year recruitment of California red-legged frog at the new pools. Besides the translocation of 16 frogs to this site from the Building 865 wetland, other California red-legged frog adults colonized the upper and lower pool areas from surrounding areas. Several egg masses were observed in both pools by the end of March; larvae were abundant in both pools and some individuals were even present beyond October of 2006. In September 2006, recently metamorphosed, terrestrial California red-legged frogs numbered in the hundreds around the periphery of both the upper and lower pools.

6.4.2.2 Rotenone Treatment of Lake Haussmann to Control Largemouth Bass

LLNL's Environmental Protection Department (EPD) collaborated with the California Department of Fish and Game to apply the piscicide rotenone to Lake Haussmann in October 2006. Rotenone is commonly used for the removal of unwanted fish species, and proper use of it poses low risk to wildlife, such as frogs. A multidisciplinary team composed of EPD and other LLNL staff worked together in the months preceding and after the application to ensure a successful, environmentally safe operation. Due to the thorough planning and expertise of both LLNL staff and the California Department of Fish and Game, invasive, nonnative fish species were successfully eradicated without any unforeseen issues arising. Water quality and sediment monitoring conducted after the application determined that no long-term negative water quality impacts from the rotenone application occurred, and that all activities were performed in compliance with applicable water quality regulations (see **Section 5.5.3**). Observations following the application confirmed that invasive, nonnative fish species that prey on the federally listed California red-legged frog population were successfully removed from Lake Haussmann.

6.4.2.3 Arroyo Las Positas

In 2006, bullfrog tadpoles and adults were observed in the Arroyo Las Positas at the Livermore site. Adult bullfrogs were removed during nocturnal surveys. Subsequent to the rotenone treatment of Lake Haussmann, sections of Arroyo Las Positas were drained to remove bullfrog tadpoles and invasive fish, including largemouth bass.

6.4.2.4 Feral Pig Control at Site 300

Site 300's invasive species control efforts have been focused largely on dispatching feral pigs. Feral pigs occupy the rangelands surrounding the site and periodically move onto the property to breed and/or forage. Control efforts initiated in 1999 have successfully reduced the seasonal pig population to very low numbers on site. In December 2006, five adult pigs (4 females, 1 male) were discovered and dispatched from the eastern side of the property.

6.4.3 Surveillance Monitoring

6.4.3.1 Wildlife Monitoring and Research

California Whipsnake. In 2002, LLNL began participating in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on the federally threatened Alameda whipsnake. At Site 300, the Alameda whipsnake is classified as the California whipsnake (*Masticophis lateralis*) because it more closely resembles an intergrade between two species: the Alameda whipsnake (*Masticophis lateralis euryxanthus*) and the Chaparral whipsnake (*Masticophis lateralis lateralis*). In April 2002, the USFWS issued a biological opinion for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to California whipsnakes. Through participation in this study, LLNL obtained USFWS approval to conduct prescribed burns necessary for Site 300 operations in areas that support California whipsnakes. The study area consists of a control site and a burn site that are vegetated by a mosaic of coastal scrub and annual grasslands. Baseline studies were conducted in spring and fall of 2002 and spring of 2003 at Site 300 and consisted of livetrapping California whipsnakes, recording the location of individuals, and marking the snakes for future identification.

During baseline monitoring in the spring and fall of 2002, a total of 18 California whipsnakes were captured (9 at the control site and 9 in the burn site). In the spring of 2003, 12 were captured (8 in the control site and 4 in the burn site). A prescribed burn was conducted at the burn site in the summer of 2003, and the first season of post-burn monitoring was conducted in the fall of 2003. One California whipsnake was captured in the control site in the fall of 2003, and no California whipsnakes were captured in the burn site. Post-burn trapping of California whipsnakes continued in the spring and fall of 2004. In 2004, there were 10 California whipsnake captures during spring trapping (6 in the control area and 4 in the burn area), and no captures during the fall trapping period.

In 2005, a total of 8 California whipsnakes captures occurred during the spring trapping period (6 in the control area and 2 in the burn area). A wildlfire, initiated off site, jumped the Site 300 boundary and burned through both the treatment and control sites on July 20, 2005. Although no whipsnake fatalities were documented during post-burn surveys, both trapping areas were burned severely and little remnant vegetation was left in the shrubland. A total of 5 whipsnakes were captured during the spring 2006 trapping period (4 in the control and 1 in the burn area). No trapping was conducted in the fall of 2005 and 2006 due to previous low capture success rates. Although the affects of the prescribed burn and subsequent impacts of the wildfire on the whipsnake is not yet known, ongoing spring whipsnake captures from 2003 to 2006 in both study sites suggests habitat requirements are still available for a portion of the population in the study areas.

Nesting Bird Surveys. LLNL conducts nesting bird surveys to ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed Kites, a California fully protected species, annually nest in the trees along the north, east, and south perimeter of the Livermore site. LLNL staff surveyed potential White-tailed Kite nesting sites using binoculars or a spotting scope during the spring of 2006; three pairs of White-tailed Kites successfully fledged young. Although White-tailed Kites are also known to occasionally nest at Site 300, site-wide Kite surveys were not conducted at Site 300 in 2006 because Kites do not typically nest in areas where they may be affected by programmatic activities.

Avian Monitoring Program. An avian monitoring program initiated in 2001 to obtain background information for the *Draft Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (U.S. DOE 2005) was continued in 2006. (See **Chapter 2, Section 2.4.1,** for more information on the environmental impact statement.) A constant effort mist netting station was also established spanning Elk Ravine and Gooseberry Canyon at Site 300. Birds were captured using ten standard passerine mist nets once every ten days throughout the breeding season (May through August 2006). Birds captured in the mist nets were identified to species, banded, aged, sexed, measured, and weighed before being released. All of the species identified in these surveys are listed in **Appendix E**.

California Red-Legged Frog Egg Mass Surveys. Diurnal visual surveys for California red-legged frog egg mass were conducted every March from 2001 to 2006 in Arroyo Las Positas at the Livermore site. Location and habitat characteristics were recorded for each egg mass observed.

The number of egg masses observed were 37 (2001), 32 (2002), 31 (2003), 9 (2004), 7 (2005) and 2 (2006). Oviposition sites tended to be shallow (22.86 cm ± 9.40 cm), and all

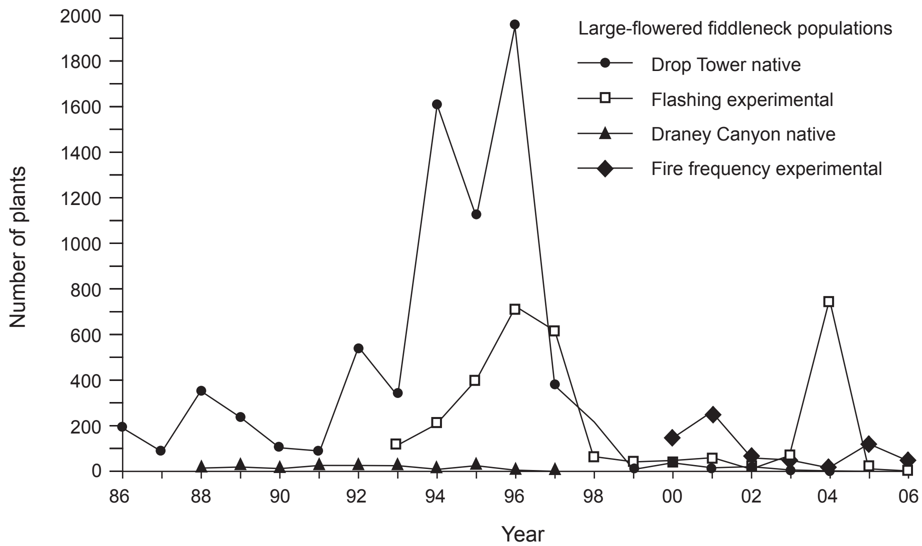

Figure 6-9. Number of large-flowered fiddleneck plants in Site 300 experimental and native populations, 1986–2006.

egg masses were located in water shallower than 50 cm. Most egg masses were within 1 m of the shore (65.29 cm ± 40.75) and near the surface (3.90 cm ± 6.25 cm). Egg masses were usually deposited on vegetation that provided structure and to a lesser extent rigidity.

6.4.3.2 Rare Plant Research and Monitoring

LLNL conducted restoration and/or monitoring activities in 2006 for the four rare plant species known to occur at Site 300: the large-flowered fiddleneck, the big tarplant, the diamond-petaled poppy, and the round-leaved filaree. The results of this work are described in detail in a biannual progress report (Paterson et al. 2007 [in press]).

Large-Flowered Fiddleneck. The only federally protected plant species known to occur at Site 300 is the large-flowered fiddleneck (*Amsinckia grandiflora*), a federally listed and state-listed endangered species. An approximate 65-ha (160-ac) portion of Site 300 has been designated as critical habitat for this plant. This species is known to exist naturally in only two locations—at the Site 300 Drop Tower and on a nearby ranch. An additional population (the Draney Canyon native population) was known to occur historically in a remote canyon at Site 300. This population was extirpated during a landslide in the 1997/1998 rainy season. The Drop Tower native population contained only 4 large-flowered fiddleneck plants in 2006, no plants in 2005, 3 plants in 2004, 5 plants in 2003, and 19 plants in 2002 (see **Figure 6-9**).

LLNL also established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. The experimental population is divided into two subpopulations known as the flashing and fire frequency experimental populations. The size of the experimental population fluctuates as a result of seed bank enhancement efforts conducted in this population. The two experimental subpopulations combined contained 51 large-flowered fiddleneck plants in 2006, 127 plants in 2005, 768 plants in 2004, 119 plants in 2003 and 67 plants in 2002 (see **Figure 6-9**). Large-flowered fiddleneck seeds were planted in the experimental population in 2006 in an attempt to boost numbers of this species in the experimental population. The exact combination of factors required to promote the success of large-flowered fiddleneck is still unknown. LLNL can promote the establishment of a native perennial grassland plant community preferred by large-flowered fiddleneck through frequent prescribed burns, but the frequent burning needed to promote native grasslands appears to negatively impact large-flowered fiddleneck. Predation of large-flowered fiddleneck seeds is quite high in burned areas and large-flowered fiddleneck is more common in area with less frequent burns.

LLNL is also beginning to see results in the long-term fire frequency experiment that began in 2001. The native perennial grass *Poa secunda* is most abundant in plots that are burned annually. Previous research shows that large-flowered fiddleneck is more successful in plots dominated by *P. secunda* compared to plots dominated by exotic annual grasses (Carlsen et al. 2000), but early results from the fire frequency experiment show that large-flowered fiddleneck is more abundant in the unburned control plots dominated by dense annual grasses than in the burned plots. Data from plots burned at an intermediate frequency are not yet available.

While LLNL has uncovered some clues to the successful restoration of large-flowered fiddleneck populations and continues to work to sustain the existing experimental and native populations, the reasons for the sharp decline in this population in recent years remain unclear. LLNL can promote the establishment of a native perennial grassland with prescribed burns, but seed predation is quite high in these burned areas.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September and October of 2006. The plant was less widely distributed at Site 300 in 2006 than in 2005.

Diamond-Petaled California Poppy. There are currently three populations of diamond-petaled California poppy (*Eschscholzia rhombipetala)* known to occur at Site 300; the population locations are referred to as Site 1, Site 2, and Site 3. Although the species is not listed under the federal or California Endangered Species Acts, it is extremely rare and is currently known to occur only at Site 300 and at one location in San Luis Obispo County. A census of the three Site 300 populations was conducted in March and April 2006, and the size and location of each diamond-petaled poppy plant were recorded. In addition, the composition of the plant community in which the species occurs was quantified.

In 2006, a total of 631 diamond-petaled California poppies were found at Site 300. The most recently discovered population, Site 3, contained by far the largest number (596 plants). Numbers of plants at Sites 1 and 2 have been very small in recent years. In 2006, Site 1 had no plants, and Site 2 had 35.

Round-Leaved Filaree. Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest portion of Site 300. This species thrives in the disturbed soils of the annually graded fire trails at Site 300. Of the six populations, four occur on fire trails. During the spring of 2006, the extent of the six Site 300 populations was mapped using a handheld GPS, and the size of each population was estimated. The six populations were estimated to contain over 5000 plants.

6.4.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2006, LLNL has been able to avoid most impacts to special status wildlife and plants. Although LLNL activities have not directly impacted the California red-legged frog at the Livermore site, a decline in the number of egg masses in Arroyo Las Positas has been observed from 2001 to 2006. The cause of the decrease is unknown.

Invasive species continue to be the largest threat to California red-legged frogs at the Livermore site. In an attempt to protect this endangered species and other native amphibians, LLNL has continued its program to remove invasive exotic species of amphibians and fish from the Livermore site. The treatment of Lake Haussmann with rotenone in the fall of 2006 was a safe and effective method of removing exotic fish from the Livermore site. Water and sediment samples were collected following the rotenone treatment. Samples were free of rotenone and its by-products 17 days following the application, and no rotenone or rotenone by-products were released from Lake Haussmann. LLNL also continued its bullfrog eradication program in 2006.

In the summer of 2005, a poorly performing breeding pool for California tiger salamanders was enhanced (deepened and widened) to more than double its original size (from 150 m^2 to 385 m^2) as compensation for the loss of habitat due to closure of the surface impoundments. The location chosen for enhancement had historically been a "sink" habitat that allowed tiger salamanders to breed during the spring period and then quickly dried before larvae could survive and metamorphose to the terrestrial stage during the summer. Successful breeding and recruitment of young salamanders to the terrestrial phase was documented at the mitigation pool in 2006, demonstrating the potential long-term breeding value of the site for California tiger salamander populations in this remote area of the site.

In 2005 at Site 300, habitat enhancement pools were created in Elk Ravine as mitigation of the impact to California red-legged frog habitat that occurred from decreased cooling water discharge. The frogs' use of the created wetlands was monitored in 2006. The pools appear to be very successful as mitigation for impacts to the Elk Ravine breeding habitat because the frogs were breeding at the enhancement pools in 2006 less than one year after their creation, and many adult frogs were observed at the pools during monitoring surveys conducted in March of 2006.

Monitoring was conducted at the Livermore site Arroyo Seco project site. Irrigation system repairs, additional planting, and weed control were conducted in 2007 to ensure the project meets the success criteria for the restoration of the site.

The Oasis and Round Valley culvert replacement projects were successfully completed in 2006, resulting in the creation of a new pool above the Round Valley project site. The pool is designed to serve as breeding habitat for California red-legged frogs and California tiger salamanders.

Although Site 300 activities did not impact the large-flowered fiddleneck in 2006, the number of large-flowered fiddleneck plants in the native Site 300 population was very low again in 2006. In 2006, LLNL continued efforts at Site 300 to maintain the experimental large-flowered population located at the Drop Tower. Through research conducted on the experimental population, LLNL is attempting to uncover the factors leading to the rarity of this species.

The diamond-petaled California poppy populations are located in remote areas of Site 300 away from programmatic impacts. Four of the six Site 300 round-leaved filaree populations are located in annually graded fire trails. In these fire trail populations, round-leaved filaree is restricted to the areas that are disturbed by grading. The disturbance appears to benefit the species and is not considered a negative impact. Although rare elsewhere, big tarplant is widely distributed throughout Site 300. Although individual big tarplants were disturbed by LLNL activities, including fire trail grading and well drilling, these impacts affected only a small fraction of the Site 300 tarplant population and are not considered to be significant to this species.